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SOME PROBLEMS PRESENTED BY SOUTH AFRICAN GRASSES AND GRASS COMMUNITIES.

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INTRODUCTION.

The grasses and grass areas of South Africa for a long time have been of interest to the botanist. They have attracted, too, the attention of the agriculturist, more especially the agriculturist concerned with crop production. During the last few years, however, an additional interest has been shown in our grasses and in our grasslands of various types, by reason of the realisation that much of the future progress of South African agriculture lies in the direction of the proper development and use of our pastoral resources.

Official support of the policy of conservation and improvement of our pastoral resources has led to an increased activity in grass and grassland investigation, by Government and University biologists pure and applied ; this activity is likely to bring to light much information of scientific and economic value. Fortunately, work accomplished by investigators such as Stapf and Stent in *systematics*, Bews and Pole Evans in *ecology*, Pole Evans, Pentz, T. D. Hall and others in *pasture and veld management*, and A. Bosman and his associates in *animal husbandry* goes far toward laying a sound foundation for research and large scale experimentation still to be attempted.

For several years certain problems in grass and grassland ecology and management have drawn the attention of those working at the Botanical Research Station of the University of the Witwatersrand, at Frankenwald in the highveld, 14 miles north of Johannesburg. Consideration of some of these problems and of those presented to me during various reconnaissances in the main grass regions of South Africa, taken together with impressions gained from reconnaissance in Tanganyika, leads me to the conclusion that a brief and simple survey of some of the outstanding problems facing investigators in this field of biology, is likely to prove helpful to younger workers.

SOME OF THE IMPORTANT PROBLEMS PRESENTED.

In outlining some of the important problems presented by our grasses and grasslands, I make no attempt to enter into detail regarding past work, or technique to be applied in the future ; I content myself with stating the problem, its bearing, and my views regarding general lines along which its solution should be approached.

(1) *Systematics.*

Stapf in his monumental work in the "Flora capensis," Stent in her various generic and specific accounts, Bews in his two books on grasses, Hubbard of Kew in his published and unpublished investigations, E. P. Phillips in his monograph on the genera of South African grasses, and Goossens in his description of some grass species have helped greatly toward our possessing a good working knowledge of the taxonomy and systematic botany of our grasses. At the same time, it would be admitted, I am sure, by one and all of these investigators that in *detail* much is still obscure regarding relationships among families, sub-families, tribes, genera and species. Concentration of attention upon certain important genera—important either on account of their value in pasture and veld management, or because of their playing a fundamental role in veld ecology—has shown how inadequate is our knowledge of the species and of the varieties making up such genera. The examples of Digitaria brought to our notice so clearly by Pole Evans and Pentz, Setaria and Eragrostis suffice to illustrate to anyone *au fait* with the elements of knowledge regarding our grass flora, the truth of my statement that we know still too little of the systematic botany of our grasses.

It is worth stressing that in addition to the obvious importance of knowing more clearly the species within genera, is the basic need of being able to differentiate important varieties of the species. It is becoming more and more definitely established in this country as well as elsewhere, that *varietal* or *strain* characteristics play a far-reaching part in determining the suitability of a particular grass for a particular object of pastoral management. Anyone in South Africa requiring to be convinced of this, should visit some of the varietal plots and experiments established at Pretoria by Pentz under the direction of the Chief of the Division of Plant Industry, Dr. I. B. Pole Evans.

While a considerable amount still could be done by systematists working in herbaria overseas and in this country, it becomes increasingly plain to anyone observing, collecting, and experimenting with our grasses in the field, that systematic work to be of the first value and service should be conducted upon plants in the field. Features clearly

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discernible to the observant eye in the field, frequently disappear wholly or in part when the plant is removed, pressed and dried, poisoned and mounted. I take this opportunity of referring to the problem mentioned in the next section—leaf and stem identification at all times of the season and under all conditions of the weather—in support of my view that the systematist must have ready and frequent access to the living plant, and to the living plant under natural conditions of the habitat : a cultivated living plant may show appreciable morphological differences from one of the same species growing under natural habitat conditions. If the systematist is to be of real aid to the collector of strains for pastoral experiments, and to the ecologist wishing to attempt an explanation of habitat and community features conditioning occurrence or dominance of strains, he must accompany these field investigators upon their reconnaissances, and must, *in situ*, sketch, colour, and describe from the living plant. Removal of living parts to the experimental plots at the base station, growth of these under known conditions of treatment, and ultimate re-description of the strain as there developed, would provide against the possibility of the single natural habitat description being made applicable to a single set of habitat conditions only.

In brief, the problem of differentiation of species and of strains must have added to it the conjoint one of enabling systematists with a field sense, to visit our grasses in the field. Obviously many practical obstacles have to be overcome : provision of financial and travelling facilities, and the selection of systematists with the flair for field work being perhaps the most difficult to surmount. As regards the first—grants for travelling could be made to Government and University systematists ; the second could be overcome by our Universities setting their faces in the direction of training systematists in the field as well as in the laboratory and herbarium.

(2) *Identification of Grasses at all times.*

In ecological and pastoral management practice it is necessary to know the grasses—and often the sedges and other associated flowering plants—at all times, under all conditions of the weather, and in the absence of flowers. While this becomes possible, with careful practice, within a limited region, over several years, it is found that the investigator accustomed to a given set of species and strains on a restricted series of soils under a given climatic complex, requires practice before he is able to identify without flowers the same species growing upon different soils under a somewhat different climatic complex. His difficulties are accentuated if not only the soils and the climatic complex, but also the species be different.

At the Research Station, Frankenwald, for example, it has been found possible for students with some experience of the seasonal change in the appearance, texture, odour and other characteristics of the grasses of the veld, to identify these rapidly and accurately without flowers, under all conditions of the weather. The same students, on proceeding to a station at Drylands, near Pretoria, showing a similar flora upon a somewhat different soil and under somewhat different aerial conditions, find it requires careful practice before some of the kinds more difficult of identification, could be referred to the correct genera and species.

From attempts that have been made to list and arrange in the form of a diagnostic key, the distinguishing characteristics of stem and leaf—and root in certain instances—it has become clear that while some of these are definite and always reliable, others are variable with seasons and with precise weather conditions obtaining. Temperature, humidity, evaporativity, and transpiration rate appear to be of first importance in altering the general appearance of foliar organs during the "green" season; during the period of "dryness" of the stem and leaf, temperature, humidity and evaporativity play some part in altering the general appearance. Each season appears to require the utilising of characteristics of both permanent and seasonal or evanescent nature—that is a *seasonal* identification key is necessary. As regards alteration of general habit due to expanding or rolling of leaves, precise ocular characteristics of hairs, etc., it has been noted that change in humidity—due to increase in water vapour or falling of rain—is especially powerful in bringing about rapid, and sometimes somewhat disconcerting, changes in the general appearance of the grass. Without attempting anything approaching a full list of the characters found of either permanent or seasonal or periodic importance in identification, I give the following as examples: (i) nature and pattern of the leaf and stem striations or other markings, if any; (ii) nature of hairs on leaf and stem and change of these with season and weather; (iii) ligule—form and other characteristics; (iv) nature of leaf margin; (v) venation—the precise characteristics, and the nature of the mid-rib; (v) nature of expanded, semi-rolled or folded, and completely "closed" leaf—and relationship existing between these states and the weather; (vi) form of apex and base of leaf; (vii) nature of stem; (viii) nature of base of stem—how protected, whether hairy or not, odour, etc.; (ix) odour and taste of leaf and stem; tasting of grass is to be done with care and not too often, as it is suspected that over-frequent tasting, with often associated inhalation, lays the taster open to infection by hay-fever, and possibly certain bacterial diseases; (x) colour, texture, odour of roots, and in some instances, taste of roots.

It is proposed to publish for some 30-40 species occurring on the Research Station, Frankenwald, seasonal and weather keys to the grasses. What is required, is that workers in their own regions should so familiarize themselves with the stem, leaf and root characters over the seasons as to be able to produce local keys, In this way, not only would all the important types of veld and region be covered in due course, but also a general comprehensive comparison of experiences, species for species, strain for strain, would be possible. University departments would find this excellent practice for students, and one capable of separating observant from rule-of-thumb prospective botanists.

(3) *Experimental Taxonomy, Genetical Cytology and Breeding.*

With the objects of separating strains, isolating true breeding species, and selecting really satisfactory material for given pastoral purposes, it is distinctly necessary that the methods of the experimental taxonomist, the cytologist, and the practical scientific plant breeder should be brought to bear upon the more important of our grasses. Digitaria, Setaria, Chloris and Cynodon alone would provide work for specialists in these lines for many years.

There can be little doubt that the subjecting of some of the so-called species of some of the very plastic genera to experimental growth methods —such as those utilised by Hall and Clements (1923) in their phylogenetic investigation of certain North American dicotyledons—would return instructive information as to the relative fixity or otherwise of these.

Additional evidence regarding factors responsible for the production of *habitat forms* or *ecads*, among the more important grasses would thus be made available. Such work would require to be carried out not only at a central base station, where experimental cultures under controlled edaphic and aerial factor-complexes could be established, but also in the natural habitats of the kinds selected—gradations of change in important factors or complexes of factors being arranged *in situ*. Herein it is that systematist, morphologist, geneticist and ecologist could join in co-operative work.

With reference to the cytological genetical work—certain of the genera (again it is in place to mention particularly so important economically a genus as Digitaria) require careful investigation of their chromosome characteristics, with the objects of throwing light upon their possible ancestry and possible relations within the genus. Cytological work, to be of the first value, must be conducted in touch with selection and growth work by the experimenter in growth and in management of the species and strains. A beginning has been made with the genus Digitaria by Young and Crocker (1933), and this work is to be continued with a number of the more important strains. A species loudly crying for genetical study supported by experimental taxonomic work is *Themeda triandra*, " Rooigras " : a grass showing probably many hundreds of strains and ecads, and economically present in forms suitable for management ranging from heavy grazing, through very light grazing, to hay production. As regards cytological work on Digitaria, a further feature of interest therewith is the non-seeding shown by so many forms and the weak to strong seeding ability shown by others ; possible correlation of cytological features and seeding capacity is being sought.

Practical plant breeding methods according to the most up-to-date technique have yet to be applied to our veld grasses. Much useful preliminary work has been done by the Division of Plant Industry at its grass stations at Pretoria, but to this must be added more precise work. Real progress in this important and difficult aspect of grass work is likely to be delayed until the problems of seed production mentioned under (5) below, have been cleared up considerably. Important material awaits the plant breeder in such genera as Panicum, Echinochloa, Brachiaria, Setaria, Chloris ; Cynodon and Digitaria, owing to seed production peculiarities, are likely to present particularly interesting material.

It must be emphasized that necessary as experimental taxonomic, cytological and breeding investigations are, they would lose much value were they to be conducted out of touch with the work of the practical collector, grower, and pasture manager.

(4) *Roots and Rooting Habits.*

If it be stated that we know very little about the aerial portions of our grasses—whether it be in terms of their structure, habit, physiology, or ecology—it could be argued that we know just about *nothing* regarding the roots. Some attention has been paid to the structure of certain grass roots by Henrici (1929) and Goossens and his associates (1933, 1934), while rooting habit has been investigated by Murray (1934) and by Murray and Glover (1935) at the Botanical Research Station, Frankenwald. It remains, true, however, that the beginning of a systematic investigation of root morphology, anatomy, physiology and ecology remains to be made. It is plain that a knowledge of the nature and functions of the roots would go a long way toward providing a better understanding of the behaviour of aerial portions, and of the ecology of communities. On the purely economic side, it is being found more and more difficult to manage veld in the absence of knowledge of the growth, reserves, and stratification of the roots of the more important grasses.

A beginning has been made with root stratification studies ; to return data of any general utility this work should be taken up in the same species in the more important soil types in the same climatic region, and in the same and other soil types in different climatic regions. Additional important species should be included region by region. Such stratification studies would return information regarding the respective depths of rooting, nature of root competition for water and solutes, relationship between rooting phenomena and *successional* characteristics of grasses in given communities, and relationship between methods of grass management and nature of roots and their food reserves.

Side by side with stratification studies in communities of different successional status, and different management history, should proceed experimental investigation of the physiology of roots—more especially in terms of water relations and storage and utilisation of reserves. Growth phenomena in roots, too, require study, and correlation with growth phenomena in aerial portions.

Root *bisect*—i.e. stratification—investigations on the basis of the methods of Weaver and his associates, but with modifications to meet local needs, have so far indicated the efficiency of the method of exposing roots and rootlets by means of a spray of water of controllable strength from a locust foot pump, followed by dissection of the roots and rootlets from the soil by means of needles. Scaled drawings and photographs, together with measurements and detailed descriptions of the roots and rootlets, are then made possible.

One of the most "knotty" problems in grass ecology is the obtaining of an impression of the depth and nature of the roots of grasses without disturbing the soil, and thus permitting a second investigation for sake of comparison, at a later date. The growing of grasses in containers, with subsequent examination, does not meet the case. Up to the present the most satisfactory of several admittedly inefficient methods is *either* to examine several representatives of a given species at a given date, and several different individuals as closely as possible resembling in size and vigour and habitat conditions the first set, at a later date ; *or* to plant a large number of specimens of a given species, in a homogeneous soil, and year by year to examine certain of these, leaving the remainder to develop until required.

(5) *Seeding Phenomena, and the raising of Grasses from Seed.*

While a large number of our grasses has been grown from seed, this, for the greater part, has been done on a very small scale only. Our scientific and practical knowledge of *when* to collect seed, *how* to collect and store it, and *when* and *how* to sow it is meagre. Some of our grasses appear to produce abundance of seed annually, others appear to bear abundantly at either longer regular or irregular intervals, yet others appear to produce little or no seed. From the points of view of the ecologist concerned with veld successional problems, the manager of artificially established and naturally established pastures, and the prospective collector and tester of seeds of our grasses, it is essential that a systematic *phenological* survey of flowering and seeding phenomena should be commenced. Such a survey should provide for the collection of data pertaining to periods of seed production, periods of ripening, periods of dispersal of seeds, periods required for adequate germination, dormancy characteristics of different species and how dormancy may be either prolonged or reduced. Methods of collection, cleaning and testing of seed on a large scale should be investigated, so as to select for each of the main species the most efficient and the least expensive method. Methods of soil preparation and tending, to produce the best germination, establishment and growth, too, require experimental study.

Some of these problems are being studied by investigators in Government service, and are receiving attention from a worker upon the Botanical Research Station, Frankenwald—Mr. T. Barenbrug, who has had extensive experience with work of this kind in Europe ; but much requires to be done. The subject lends itself to student investigation over a period of several years, and hence could be taken up by our Universities.

(6) *Growth Phenomena.*

It has been indicated in connection with the problem of root growth that we require more information regarding season, rhythm, and nature of growth in grasses. Several small-scale observations have been made by means of auxanometers and direct measurement, but species by species, community by community, growth phenomena over the relevant periods of the year require to be investigated on a systematic basis and on a liberal scale. In connection with problems of when to graze lightly or heavily, when to mow, when to fertilize with chemical and organic fertilizers, when to plant for most rapid growth and best competition with weed growth, knowledge regarding rhythm of growth is a basic need. Specific differences in terms of periods of maximal growth may be of the first importance when it is desirable to encourage one set of grasses and to retard or eliminate another.

Much may be done by direct observation and measurement of selected individuals of the required species, frequent—sometimes daily—attention being a necessity for success.

(7) *Succession Details.*

While Bews has done a very great deal to present a general picture of successional features in grassland in South Africa, with special reference to Natal, it is perfectly evident to any student of grassland ecology and management that every region, every district, every community type requires careful investigation before reliable details of direct utility to ecologist and manager of veld are available. I have given some outline elsewhere (Phillips 1934; 1935; 1935A) of the many difficult features presented the student of *succession, development,* and the *climax community,* hence it is not necessary to do more than refer to the highly complex nature of this interesting and important phenomenon, and to emphasize that in a country of the diversity of micro-climates and soils shown by South Africa, many features in grassland succession by no means have been investigated. Fundamentally important questions scientifically and economically include these: What is the climatic climax for a given region ? What are the principal stages in the successions in a given region ? How may such stages be accelerated or retarded in their development toward the climax ? What are the results of attempting to control the climax at a given point, according to a given season and method ? What bearing upon *successional retardation* or *acceleration* or *deflection* (vide Phillips 1934), have prevailing methods of grazing, soil cultivation, and burning of vegetation ? While our knowledge of the aerial portions of important species within *successional* and *climax* communities is all too meagre, it must again be emphasized that we know just about *nothing* regarding the root changes accompanying *successional* changes.

Within each principal region, it is strongly desirable to investigate the *successional* features and tendencies, and to do this on an experimental basis—in terms of protection, subjection to controlled grazing, controlled seasonal firing, and the like.

Although much of this work may appear of purely academic interest —it is the duty of the ecologist to stress that in reality it is the foundation upon which the success of the student of pastoral control most surely rests.

(8) *Cyclic Phenomena.*

Cyclic phenomena in Nature—sunspot cycles, rainfall cycles with resultant growth cycles in vegetation—have received much attention of recent years in the United States, and to a lesser extent in Europe. They certainly appear worthy of some attention in South Africa. The recent flush of growth in grass communities in many portions of the Union, following two seasons of somewhat higher rainfall than those preceding, has been an instructive phenomenon. In many parts *Themeda triandra* or "Rooigras" has shown a remarkable capacity for reappearance as a dominant over areas where for some years it has been but poorly represented, while the appearance in certain parts of tall Cymbopogons and Andropogons and other grasses of the stages leading to a Scrub climax is most interesting. Attention is being paid to possible correlation among sunspot cycles, rainfall cycles and peculiarities in the growth-rings ("annual rings"), in certain deciduous indigenous trees of the Transvaal highveld, with the object of seeing whether the record of growth-rings in such trees is in any way an index to past moister or drier cycles, and whether there be any remote possibility of future cycles being predictable on grounds of the evidence of the past. If investigators in different regions of the Union were able to agree upon the selection of a common indigenous tree species widely distributed—e.g. *Acacia caffra* or *Zizyphus mucronata*—and were to follow common methods in attempts at correlation, a really considerable body of proof *for* or *against* the possibilities mentioned, would be obtainable. Dr. A. E. Douglass, a pioneer investigator of cyclic phenomena as indicated by growth-rings in Sequoia and other long-lived tree species in North America, and by certain European species, recently has founded a society in America for investigation of such phenomena, and is publishing a journal presenting the results.

(9) *Fire : Its Influences in Grassland Vegetation.*

I have published elsewhere my views regarding the role of fire in vegetation in South and East Africa (Phillips 1930), and added experience since the writing of that contribution makes me all the more inclined to support the views put forth therein. Fire, according to the species of grasses concerned, the successional rank of the community, the vegetation region, the season of the year, the nature of the season in terms of moisture and temperature, and probably other conditions presently not fully understood, may do either considerable harm or may do much good. Staples (1926 ; 1930) has shown the great importance of season of burn upon Themeda ; experiments being conducted since 1931 at the University of the Witwatersrand, Milner Park, in Themeda communities go to support in general the experiences of Staples : burning at one season may encourage growth and development to dominance of "Rooigras," whereas at another, burning may be direct cause of either considerable reduction or complete disappearance of the species. Other important dominants possibly present similar responses, but little or nothing is known about them.

Seasonal firing, with and without the additional feature of earlier or later grazing of the fresh growth springing up on the burned area, requires far more detailed regional and community investigation than it has received. From evidences being produced from consistent observation and from general experience, it is tolerably clear that fire must continue to play an important role in veld management in South Africa, provided it be more fully investigated, and provided it be used with considerable care as to season. It must be stressed that the problem is not one purely of season of firing, but rather one of season of firing and related season of grazing of the burned area ; nature of the grazing, the weather conditions obtaining at the time of grazing, and the general nature of the season are likely to introduce important complications.

Carefully conceived and uniformly executed experiments upon seasonal firing in different communities, in communities at different stages, in different districts, and in different regions require to be laid down by Union investigators working in collaboration. In the first instance, the complications springing from grazing of the burned areas should be left out of consideration, special arrangements being made for these later.

At all events, our present knowledge indicates that indiscriminate firing is not much more harmful in grassland management than is indiscriminate with-holding of fire.

(10) *Grasses and Grass Communities in relation to Grazing and Browsing.*

Without attempting to deal with the manifold problems of the grazier and the student of animal husbandry, it is necessary to refer briefly to the problems set by the influence of grazing and browsing upon grassland communities. It frequently is stated by the layman that heavy or "over" grazing is responsible for denudation of the soil, but it is less often realized that over-grazing actually often has precisely the opposite effect : acceleration of the growth of the woody elements of the flora by removal of the competing grasses. This brings me to a point that might well have been made under the heading (7) dealing with *succession*—in my opinion it is extremely doubtful whether in the Union more than rather local areas in the colder regions of the Free State and Southern Transvaal—e.g. in the Standerton area—truly are *climax* grassland. I base this suggestion upon the sometimes relict, sometimes very abundant woody elements—constituents of a Scrub community—to be found in almost all the other regions rich in grassland. Over-grazing reduces the grasses; grass reduction means less competition with the shrubs and small trees for moisture and solutes, and the impossibility of grass fires normally destructive to the Scrub; Scrub kinds, therefore, increase, and in time build up a more or less closed *climax*. Any area within a region in which development is to Scrub, on the other hand, tends to become covered with coarser grass, with perennial herbs and shrubs, if the grazing to which it is subjected be insufficient to keep the succession at a suitable grass stage.

Early grazing may spell the reduction or elimination of certain early species, whereas late grazing may reduce or eliminate in time later species: therefore the phenology of the species must be studied in relation to the grazing system proposed.

Light grazing of a community may mean highly selective taking of certain species, and more-or-less complete rejection of others, whereas the same community, if more heavily grazed may have a far greater number of species taken.

Numerous other examples of plant - animal interrelations could be cited, but sufficient has been said to warrant the conclusion that our grasses and our grassland communities require very careful experimental study in relation to the kind of grazing to which they are subjected. Browsing animals, it is to be remembered, may have profoundly different influences from grazing animals.

Attempts to throw light upon some of the many problems set by the animal-plant relationship are being made by the Government authorities concerned, by the Agricultural Adviser to African Explosives and Industries, by the Faculty of Agriculture at the University of Pretoria and the Botanical Research Station, Frankenwald.

(11) *Zoo-biotic problems.*

While the zoologist naturally is loth to pay attention to zoo-biotic problems set by domesticated stock, it is not too much to expect him to take some interest in the problems connected with important indigenous animals. So far there has been a curious lack of enthusiasm on the part of most zoologists to take up any of these problems.

It is sufficient for my purpose to refer to termites and to smaller rodents—rats and mice. Termites of various species play a fundamentally influential role in grassland vegetation in South Africa. Among them are forms distinctly beneficial through their soil improving, soil aerating, organic matter producing activities; among them are distinctly harmful forms—such as the Hodotermes—responsible for much grass-cutting during the drier seasons of the year; some forms are alleged to take heavy toll of the grass seed in lean years. At all events, our knowledge of these helpful and harmful forms is all too scant, and our knowledge as to how to control the harmful forms, on a large scale, is negligible. Zoologists with a flair for ecological work are earnestly required for this class of investigation. The smaller rodents in some seasons eat grass roots, grass seeds, and help in dispersing seeds; they also, in their colonies, appreciably open up the soil. In areas where they are abundant, their study is long overdue.

(12) *Indicator significance of certain communities.*

Clements (1920) has developed the concept of plant indicators, and I have dealt with principles and details for indicators in the Knysna forest region (Phillips, 1928; 1928A); so far as I am aware, no published information regarding indicator communities in grassland is available for South Africa.

In grassland, indicator communities should prove of the greatest possible utility in pointing to the past history of development, and to the future possibilities of management. From our experience upon the Botanical Research Station, Frankenwald, it is possible to select for general working purposes communities, pure or mixed, that throw light upon:—(i) Past history of the area, in terms of disturbance or management; (ii) future possibilities of the area in terms of management; (iii) successional status of associated vegetation; (iv) important edaphic conditions, such as higher, medium, or lower moisture content; presence of an impermeable pan below the surface; whether the soil has been disturbed by ploughing or other form of cultivation, and at what approximate date in the past.

Region by region, soil type for soil type, community for community, such indicator work is required; not only would this return most valuable information for the student of pastoral management, but it would provide fascinating material for the ecologist.

Connected intimately with the concept of plant indicators is that of *phytometers*, again due to Clements (*vide* Clements and Goldsmith, 1924; Clements and Weaver, 1924); a phytometer being a "standardized" plant, the responses of which (in terms of transpiration, amount of photosynthate, growth, anatomical and morphological features, general phenology, etc.) are measured in a given habitat. (For South African work on *phytometry, vide* Phillips, 1925; 1927). As grasses grow so rapidly, are often so very sensitive in their responses to light, humidity, soil moisture, chemical solutes and the like, it has been suggested from time to time that they should prove useful phytometers. So far the work done by two of my students—Mr. H. Gillman and Miss A. Brownlees—upon several species of Digitaria (*D. valida v. glauca* Stent; *D. seriata* Stent, being the "Pretoria Small" and the "Kuruman" strains of Digitaria respectively), has shown some of the great dificulties connected with the use of stoloniferous plants as phytometers. As control phytometers have to be kept in containers which have to be sealed against rain and against loss by evaporation, stoloniferous grasses fail to grow adequately, owing to the impossibility of their stolons finding their way out to the light, and then back to the soil within the pot. Work on grass phytometers, however, is well worth further attention in the light of the rapid growth of the material.

Phytometer cultures in either unsealed containers, of large size, or in the open ground, are likely to prove useful for purposes of rough comparison of sites. Controlled phytometers, made up of non-stoloniferous grasses, however, are worthy of trial.

One of the objects of referring to the difficulties encountered in attempts to make phytometers from stoloniferous grasses, is to indicate how complicated is the problem of obtaining adequate data regarding the water relations of stoloniferous grasses, water relation technique depending so directly upon the sealing of containers against rain and evaporation.

(13) *Special methods of investigation.*

Grasses in their growth-forms, nature and rapidity of growth, and ecological characteristics present many problems as to methods of investigation likely to prove productive as well as workable in practice on a large scale. Probably in the sphere of community investigation, popularly known as "grassland analysis," this is more definitely brought out than in any other. Methods of analysis productive of satisfactory results within a reasonable period in forest, scrub or "fijnbos" (macchia) communities, in most instances usually are not applicable, without considerable modification, to communities of grass. So much is this truth forcing itself upon me, that for some time my students and I have given serious attention to the selection of methods possible and efficient for given purposes in grass communities; the further we proceed, the more we realise that even the very best of methods so far available, are by no means satisfactory. In one method, efficiency may be satisfactory but the possibility of carrying out the method as a routine one, on a large scale, is out of reasonable consideration; in another, where speed is satisfactory, one or other technical feature leaves something to be desired. It is furthermore clear that the method of analysis selected must to a great extent depend upon the objects hoped to be attained; indiscriminate application of so-called " standard " method not only is unscientific in principle, but is likely to return little useful at the end of many days or weeks of hard field work. Investigation is proceeding, with special reference to the peculiarities of our grassland communities in terms of growth-forms of grasses, espacement of individuals or groups, abundance of plants other than grasses, nature of the community, and precise objects of the experiment and of the analyses. So far, depending upon the foregoing *inter alia*, we are finding our own modifications of Raunkiaer's analysis circle, the density-cover list quadrat, the camera-chart quadrat, and the photograph-quadrat effective up to a point. Pantographic methods so far attempted appear cumbersome and liable to variable error, but probably hold within them the basis of modifications really rapid and efficient.

Plant photography is by no means an easy aspect of photography, but the photographing of grasses under field conditions is certainly one of the most trying aspects of this difficult subject. Critical focusing, critical use of apertures and exposures, and careful selection of filter and of angle often are ineffective in giving depth and detail where these are essential for purposes of scientific record. Stereoscopic methods have something to commend them, and are being tried with some success by a former student and colleague, Mr. J. D. Scott, now of the Division of Plant Industry.

Problems in physiology technique have been mentioned under (12) ; these require earnest attention if any real value is to be yielded by grasses grown in containers.

Habitat factor analysis—all too frequently left out of account in grassland research, because it is thought that aerial conditions are so similar as to play no important role, and because chemical analysis of soil alone is considered as being of any importance among the edaphic conditions—presents some special problems as to methods likely to provide information precisely bearing upon factors regulating responses in the grasses.

CONCLUSION.

From the foregoing outline of problems, it is clear that grasses and grass communities in South Africa provide material to set investigators, with various interests, thinking hard, and experimenting with minds receptive for suggestion emerging from increased experience. Thus this field of investigation, in addition to adding much information essential to the solution of our national pastoral and erosion problems, provides ample scope for the student of pure science, and for the investigator who at the same time is interested in experiments in scientific, more especially, botanical education.

SUMMARY.

Important problems are mentioned as existing in the following :—Systematics ; identification of grasses at all times ; experimental taxonomy, genetical cytology and plant breeding. Ecology of roots of grasses. Seeding phenomena, and the raising of grasses from seed. Phenomena of growth, with reference to methods of pastoral management. Successional features, details, and principles, community by community, region by region. Cyclic phenomena, such as growth-cycles, sunspot cycles, and rainfall cycles. Fire, and its influences upon grasses and grass communities. Grasses and grass communities in relation to grazing and browsing by domesticated stock. Zoo-biotics, especially rodent and termite problems. Indicator significance of certain communities. Special methods of investigation in grassland :—ecological community analyses ; photography ; and habitat analyses.

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